<u>Learning in a Project-based Human Biology Unit: *I, Bio*</u>

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<u>Project-based Science Aims for Standards-based Content Learning</u>

This poster focuses on *I, Bio*, a middle school project-based science unit developed by the Center for Learning Technologies in Urban Schools (LeTUS). This unit teaches core life science content about the integrated function of organ systems transforming energy in the human body in the context of students using this content to complete an authentic and personally-relevant project in which they redesign their school lunch choices to meet their bodies' energy needs. This project-based mode of instruction aims to support students' ability to use the life science content they learn by helping them build the integrated knowledge structures and conditions of applicability that typify expertise. Consistent with modern research on how people learn, exposing students to the big ideas in a domain as they arise naturally in the context of problem situations is one way to achieve this goal (Bransford, Brown & Cocking, 1999). Learners introduced to a discipline's core content when they can see a need for using this content are better prepared to apply this content in novel problem-solving situations. It is for this reason that *I, Bio* aims to teach life science content within the aforementioned project-based context.

However, given the current climate of accountability in schools, a project-based science unit such as this, for all its potential benefits, must also ensure that students learn content of a breadth consistent with the reality of standards-based assessments. Students engaged in a project-based science curriculum might not achieve target content learning goals because, as Sherin *et al.* point out, project-based curricula by their very nature do not build up content in a traditional taxonomic sequence. The needs of the project dictate what content and the depth to which that content must be learned. Therefore, there can be a tension between learning the content required to complete the project and learning the breadth of standards-based content required to perform well on a given standards-based assessment.

Although we believe the *I, Bio* project to have been designed to support learning grade-appropriate standards-based content in a manner consistent with also learning to usefully apply this content, we attempted to assess the extent to which middle school students with whom the *I, Bio* unit was piloted learned content in both these ways.

<u>*I, Bio*: Project-based Life Science Middle School Unit</u>

At the heart of the *I, Bio* unit, middle school students complete a design project to explore how well their school lunch choices meet their bodies' energy needs. Students redesign their school lunch choices until a measurement of the energy their school lunch choices add to their bodies' energy stores is equivalent to the energy their bodies use up from their stores doing work. Completing this design project, students acquire and employ knowledge of how their bodies' organs and organ systems interact to transform energy in food into energy used up doing work, and how their bodies' organs and organ systems interact to provide all cells' energy needs.

I, Bio is structured into three spirals. Each spiral takes the student for a deeper pass through the same content and concepts, helping students gradually make progress on the design project. Spiral One, Introduction to the School Lunch Project, motivates the project. In addition, Spiral One presents the driving question that frames the design project: how well do my school lunch choices meet my body's energy needs? Over the entire rest of the unit, students' subsequent questions derive naturally from this driving question and guide the learning that prepares the students to complete the design project. In Spiral One, we catch students' attention by having them read excerpts from the book *Hatchet* by Gary Paulsen. *Hatchet* is a story about a boy their age surviving on his own in the woods, having no tools but his hatchet. *Hatchet* allows us to begin the unit with the concept of biological work. Students find that their bodies perform a variety of activities, all of which we call work. Students then brainstorm about what their bodies need to do this work and conclude that their bodies need energy that comes only from food. By posing the question, "Why don't we need to eat all the time?" students find that the body has stores of energy. Food adds to these energy stores and doing work depletes these stores. After learning why it is healthy to balance the amount of energy taken in with the amount of energy used up, students debate the different amounts of energy that certain foods and activities are "worth." This is a point in the unit designed to reveal students' prior conceptions. Students combine the results of their debate with a "body bottle" activity to tangibly mimic the ebb and flow of the body's energy stores. By observing the level of energy in their body bottles over the course of a day, students address the question they've been working toward: "How do my choices affect my energy stores?" They discover that they must <u>measure</u> the amount of energy they take in and the amount of energy they use up and compare these two numbers to know if their bodies are in energy balance. In this way, Spiral One builds placeholders for the two quantitative tools students will need to devise (measuring energy taken in via food and measuring energy used up doing work) to complete their design projects.

Spiral Two, The Tools to Conduct the School Lunch Project, helps students acquire the two quantitative tools essential to carrying out the design project: the ability to measure the energy taken in in the food one eats and the ability to measure the energy used up doing work. Each of Spiral Two's halves is devoted to one of these two quantitative tools.

The first half of Spiral Two, Measuring Energy Taken In By The Body, concerns itself with measuring the energy in the food we eat. Students begin the first half of Spiral Two with the question, "How do I know there really is energy in food?" Students get more specific than they had been in Spiral One about what it means for food to contain energy. They discuss transforming food's stored energy into heat via burning to prove there is energy stored in food. As students do experiments using a gaseous oxygen sensor to compare their own exhalations to room air, they test how similar burning food is to how food energy is transformed in their bodies, and students find that oxygen is used up in both cases. Students return to the task of measuring the energy in food. Students find that food energy, transformed into heat, can be measured through direct calorimetry. Students design and conduct experiments with direct calorimeters to measure the energy stored in different foods. In order to answer the question, "How much food energy do I take in?" students log the amount and types of foods they eat for lunch. Students then use their food logs along with the quantitative results of their direct calorimetry experiments to calculate how much energy their bodies are taking in.

In the second half of Spiral Two, Measuring Energy Used Up By The Body, students learn to measure the energy expended by the body's work. Now students get more specific about what it means to do work. As they debate about where the body's work is performed, students learn that all work is a function of specialized body cells. Through hands-on experiments, students find that the complex work of multicellular organs is rooted in the work of single cells. Students make the connection that energy is used by the cells since that is where work is actually being done. Students learn about cellular respiration. Students explore the related issue of delivering foodstuffs and oxygen (the raw materials to transform food energy into cellular work) to the cells. Students conduct experiments and work with reference materials to figure out how foodstuffs and oxygen reach the working cells. In this way, students develop a basic understanding of how the digestive, respiratory, and circulatory systems work together to support the vital function of transport necessary for cellular respiration. All together, the second half of Spiral Two supports students designing and measuring via indirect calorimetry the amount of energy they use up doing work. Students design experiments to collect their expired air while performing different types of work and measure the difference between the quantity of oxygen they inhale and exhale using the gaseous oxygen sensor and related equipment. These indirect calorimetric measurements combined with students' logs of their activities allow students to measure the amount of energy their bodies use up doing work. After completing both halves of Spiral Two, students are equipped with the tools to measure both the food energy taken in by their bodies and the amount of energy their bodies use up doing work.

Students are now prepared for Spiral Three, Completing the School Lunch Project, in which they complete the school lunch design project itself. Students redesign their school lunch choices— taking into consideration the constraints to which they typically adhere (these constraints reflect students' personal choices about diet and exercise as well as the "food pyramid")— until a measurement of the food energy their lunch choices add to their bodies is equivalent to the energy their bodies use up doing work. During Spiral Three's design process, students generalize the basic principles that affect the success of their designs, present these findings class-wide, and share and employ these ideas to further improve their designs.

Results: Assessing Content Learning in *I, Bio*

The *I, Bio* unit was piloted in a public middle school located in a mid-sized, urban city in the Midwest. The school enrolls approximately 600 students from a range of ethnic backgrounds and socioeconomic circumstances. The student population is evenly split between white (47.6 percent) and non-white students (35.1 percent black, 15.1 percent Hispanic, 2.2 percent Asian or Native American). Just under one third (29.1 percent) of students fall under the state's "Low Income" category, which includes students eligible to receive free or reduced-price lunches, or that come from families on public aid. In recent years, school and district officials have struggled to manage the diverse array of students' learning needs, including a substantial achievement gap between whites and blacks.

I, Bio was piloted by one teacher, Jane, in three 7th grade classrooms. Jane majored in biology and has 3+ years of science teaching experience. During Jane's piloting of the unit, she met regularly with university researchers to plan lessons, create materials, and review students' progress. Most of Jane's 61 students had previous experience with the specific pedagogical approach to project-based science used in *I, Bio*, including the use of sustained investigations, student collaboration, and the integration of technological tools.

Over the eight-week period of Jane's *I, Bio* pilot, researchers collected several forms of data, including student work, video recordings of class sessions, field notes, pre- and post-tests, and pre and post student interviews. The pre- and post-tests for *I, Bio* were developed as part of an ongoing assessment program started by the Learning Outcomes Group (LOG) of the Center for Learning Technologies in Urban Schools (LeTUS). LOG has been developing instruments and techniques to assess student learning in project-based science classrooms for several years (Herman *et al.*). Similar pre- and post-test instruments have been developed for LeTUS's task-structured science units about animal behavior, global warming, earthquakes and volcanoes, water quality and other science content. The purpose of pre- and post-tests like the one developed for *I, Bio* is to bridge the gap between "close" forms of assessment – class worksheets, journaling, papers, and other assignments that follow classroom instruction – and "distal" forms of assessment – standardized and other exams based on standards in a particular domain (Ruiz-Primo *et al.*).

The pre- and post-test developed for *I, Bio* is a "proximal" measure of achievement—it assesses knowledge that is important in the unit, but uses topics that students have not been exposed to (Ruiz-Primo *et al.*). Proximal assessments can be based on analyses of a particular discipline or domain, implicit or explicit learning theories in the domain, previously identified student misconceptions, and/or relevant district, state, and national standards. In developing the *I, Bio* pre- and post-test, the particular middle school life science standards addressed in the unit in addition to student misconceptions received greatest emphasis (although as we continue to study enactments of *I, Bio*, it will eventually become possible to craft assessments around concrete theories of how students learn this specific content). The design of the instrument was hampered by the usual constraints—e.g. time available for testing and student characteristics—that limit the number of items that can be tested, the kinds of tasks that can be assigned, and the phrasing of particular items. Even with these constraints and the need for refining and adding different items the designers feel the instrument serves as a useful indicator of content mastery.

The test has 21 multiple-choice and short, constructed-response items (see Appendix 1). Eleven items cluster around assessing students' understanding of grade-appropriate standards-based life science content including: cells as the most basic unit of living things (item 2); the relationship between cell structure and function (item 4); the relationship between breathing, pulse rate, and work (items 6a and 6b); the function of blood (item 8); the three major organ systems involved in transforming energy from food (items 9a and 9b); the transport of energy's "raw ingredients" to cells inside the body (items 10a, 10b, and 10c); and the role of cells in transforming energy to do work (item

14). Nine items cluster around assessing students' understanding of the body's use of energy and the body as a reservoir of biological energy, which is not typical standards-based life science content but is content learned in the context of doing the *I, Bio* project (we'll call this "project-based content"), including: voluntary and involuntary forms of work (item 1), the body's ability to store energy (items 3 and 5), different foods as sources of energy (item 7), the physical properties of energy (item 11), the relationship between the body's use of energy and work (item 12), the role of oxygen in energy transformation (item 13), and health strategies that align dietary choices with the body's energy needs (items 15a and 15b). There is one additional item about vitamins and minerals in food (item 16) that falls outside of these two major clusters; the results for this item will not be reported here. The pre- and post-test is expected to measure growth in these two major clusters: Question Cluster 1- standards-based life science content, and Question Cluster 2- content outside of the life science standards but equally necessary for doing the *I, Bio* project (project-based content). Since the knowledge being measured here by this "proximal" measure of achievement lies at some remove from the actual activities of the unit, we assumed that improvement on the test would also be indicative of students being better able to apply aspects of this content to new contexts.

Forty-six of the 61 students participating in the *I, Bio* pilot study returned both pre- and post-tests. The remaining students were absent during one or more days of testing. The magnitude of the statistically significant ($p<.001$) mean difference score (1.89) and effect size (0.51) reported in Table 1 are in line with results collected using similar instruments devised by LeTUS to measure student learning of evolutionary biology, global warming, water quality and geology content (Herman *et al.*). The figures denote modest gains in student knowledge of *I, Bio* related content. The mean pre-test score (7.87) for Jane's classrooms indicates that her students possessed important knowledge about human biology and energy before participating in *I, Bio*. The pre-test average exceeds the 3- to 4-point reward expected for random guessing, but leaves ample room for improvement. More specifically, most of Jane's 7th grade students' were able to identify cells as the most basic unit of living things (item 2) and could explain that fire requires oxygen to burn (item 13). Many students also knew the correct functions of blood in the body (item 8) and could calculate a net energy gain for a hypothetical student (item 5). The success rate for these items was high and did not dramatically improve during Jane's enactment. On the other hand, students appeared to believe that only voluntary activities require energy (item 2) and most students could not identify cells as the place where energy is changed into the body's work (item 14). The initial success rate for these items was low, but increased markedly on the post-test. (See Table 2.)

The post-test results offer a picture of the learning that occurred in Jane's three *I, Bio* classrooms. The overall improvement from the pre- to the post-test is largely composed (Table 1) of a statistically significant ($p<.05$) mean score increase (0.59) and effect size (0.31) for Question Cluster 1 related to cells and organ systems as well as a statistically significant ($p<.001$) mean score increase (1.17) and effect size (0.62) for Question Cluster 2 related to the body as a reservoir of biological energy. It would appear that students' content knowledge increased significantly in these two broad content areas, one of which is more closely aligned with the life sciences standards, the other more closely aligned with the project's content needs. This appeared to be the case even though this was Jane's first experience teaching the *I, Bio* unit, and in classrooms teaching project-based units like *I, Bio*, students' pre- and post-test performance is likely to improve as teachers develop more facility with the targeted content and pedagogical approach. The small number of students participating in the initial pilot study also suggests that these results should be verified; the picture of student learning of the content covered in *I, Bio* will become substantially more robust as additional teachers elect to teach the unit in their classrooms, and as student demographic information and standardized test scores (currently unavailable) are added to the assessment picture. Nevertheless, we report modest gains in students' knowledge of content related to cells and organ systems as well as the body as a reservoir of biological energy. Again, since the knowledge being measured in the test lies at some remove from the actual activities of the unit, we assumed that such improvement in test scores was also indicative of students being better able to apply aspects of this content to new contexts.

Clinical interviews before and after pilot instruction during *I, Bio* were designed to verify the extent to which test scores were indicative of an improved ability to apply or use the target content knowledge. The clinical interview protocol begins by asking students questions of the form: What would happen to your body's energy stores if you ate these foods and engaged in this particular sequence of activities? However, prior to instruction, it is unlikely that any such question that refers to changes to "your body's energy stores" would be sensible to students. We therefore thought that it would be more sensible to pose questions about which foods and activity choices would be "healthy" as a minimal prompt to see the extent to which students associated health with biological energy levels. We simply wanted to activate students' ideas and explore these ideas. For this reason, we started our interview with a very open question. We asked students to imagine that there was a student just like themselves (same age, gender, etc.) who wanted to stay healthy over the next two or three days. We then asked: What choices should this student make in order stay healthy? After this initial part of the interview, we asked more structured questions to further probe the shape of the student's already activated knowledge and activate additional knowledge. Much of this structured questioning was conducted around some sheets of paper that showed a particular food or activity along with some relevant data. For example, some of these information sheets resembled the nutrition labels that are found on commercial food items (Figure 1).

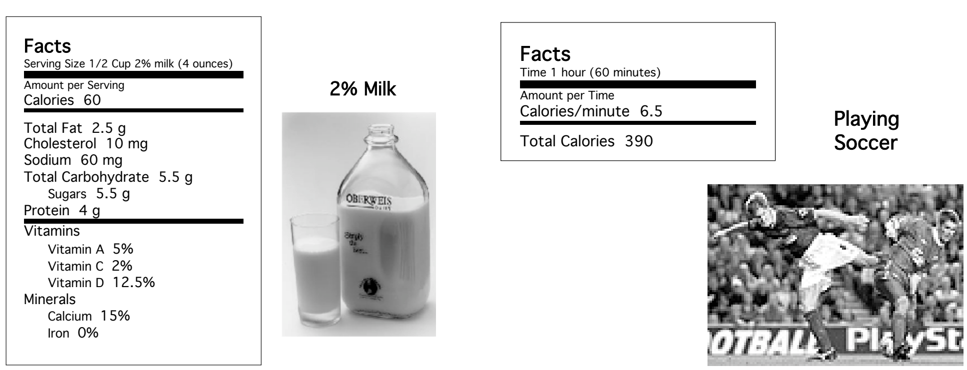

Figure 1. Sheets showing food and activity items along with relevant data.

This series of questions was followed by another series that asked interviewees to diagram how the "healthy" parts of the food move where throughout the body and with the help of what organ systems. We provided students with a blank diagram of the body and asked them to draw where the food goes and label all the parts or systems involved. We followed this open question with more structured questions about what parts or systems are involved in getting the energy in food where it needs to go in the body and the specific role breathing might play in this process. The clinical interview protocol can be found in Appendix 2.

These clinical interviews were conducted with just a few students selected by the teacher, Jane, as representative of a high, medium, or low achieving student based on grades, participation, and standardized test scores. Of the students for which we collected matched sets of interviews (Table 3), we will focus here on just the interviews conducted with students T. and L. T. had pre-test scores in question clusters 1 and 2 (2 and 3 points, respectively) below the class pre-test averages (3.78 and 3.54 points, respectively) but post-test scores in question clusters 1 and 2 (5 and 5 points, respectively) above the class post-test averages (4.37 and 4.72 points, respectively). Similarly, L. had pre-test scores in question clusters 1 and 2 (3 and 2 points, respectively) below the class pre-test averages and post-test scores in question clusters 1 and 2 (5 and 5 points, respectively) above the class post-test averages and identical to L.'s post-test scores. We focus on these two students' interviews because their patterns of scoring are similar to one another (and in the post-test identical) and of a type that would have had a very significant impact on the observed class-wide improvement in Question Cluster 1 about standards-based content knowledge related to cells and organ systems and in Question Cluster 2 about project-based content knowledge related to the body as a reservoir of biological energy. The results of these clinical interviews will allow us to better verify the extent to which the improvement in class-wide test scores is indeed indicative of students' improved ability to apply this content to new contexts, both the cells and organ systems content that is most closely aligned with the life sciences standards, as well as the content about the body as a reservoir of biological energy, which is not typical standards-based life science content but is content necessary to complete the project.

The following interview episodes show how both T.'s and L.'s responses to the first part of the clinical pre-interview are similar to one another with regard to certain previously held ideas about the body as a reservoir of biological energy: that exercise, sleep, and vitamins and minerals are among things that give the body biological energy. These clinical pre-interview responses will provide a basis for comparison.

1	Interviewer	So imagine that there's a kid like you, student, young lady, 7th grade girl and you want her to stay healthy over the next couple days. So, what kinds of choices would you make for that girl to keep her healthy over the next couple days? … OK, um, and, but you also mentioned that she was going to exercise, I think, did you say? So, I was wondering what about exercise keeps you healthy?
2	T.	Um, it, it really keeps our body in shape and like and if you exercise sometimes it just it helps your body because like, a lot of people do it, like I exercise and it helps me. And it gives you and if you exercise and eat healthy food you'll have a lot of energy, I think.
3	I.	Does anything else give you energy?
4	T.	Well you rest, you rest while you are sleeping and then when you wake up you are a little bit tired but once you eat something, like once I eat an apple or an orange or something like that, and then you start walking and that just gives me energy.
5	I.	So you're trying to give her vitamins to keep her healthy? … So what do vitamins do for you that keeps you healthy? Is there something that they do for you?
6	T.	They like well they give you energy also, and they also keep your body healthy, I don't know, I just know that they keep your body healthy, but I don't know if they have something special.

7	Interviewer	So the first thing I want to do is imagine that there's a student like you. And I just want us to think about what sort of choices she should make to stay healthy. … So you said vegetables are good because they have vitamins in them, is that right? And why is that good?
8	L.	Like, to give you energy, I guess. Like iron. I forgot. My mom told me what iron is in, but I forgot what it was. And iron gives you energy.
9	I.	And how about energy? Does energy, is that the same as the vitamins and iron?
10	L.	It depends. You could be taking something and get more energy or you could just, like, sleep.

Even with specific prompting to attend to the calories for food and activities listed on the information sheets, neither student reasoned with this information in the clinical pre-interview in response to questions about energy or weight in re. health. In the pre-interview, in these students' conceptions, food's calories or the body's work were not related to changing the body's stores of biological energy and thereby body shape or size. These students responses seem to be consistent with low pre-test scores on question cluster 2 being indicative of these students not having the ability to use this content in context.

In response to the second part of the clinical pre-interview, which focused on cells and organ systems, we find the following responses that describe T.'s unusual conceptions about cells and connections between breathing and the circulatory system.

11	Interviewer	Where are the cells?
12	T.	Like, they are all over. … The cells, they flow all over. Like red blood cells.
13	I.	Are there cells like in your little toe?
14	T.	I don't know. I don't think so. I don't know because cells are very small, so I wouldn't really be able to tell.
15	I.	What about breathing, does that have anything to do with getting the energy?
16	T.	The who? Breathing? Um well, I'm not sure. I know, air needs to come out and air needs to go in.
17	I.	Why?
18	T.	I don't know, I think it does have to do with the whole system but
19	I.	… So you need something that's in the breathing?
20	T.	Yeah, the oxygen.
21	I.	What do you need that for?
22	T.	Um, I don't know. Maybe just, I don't know.
23	I.	Where does it get to, the oxygen that you are talking about?
24	T.	It gets somewhere over around here, because I know that if it doesn't get somewhere over here and it doesn't get in your body, your heart stops beating.

In contrast to T., in her pre-interview L. had more developed ideas about cells but she was not without unusual conceptions, as well as unusual ideas about connections among the digestive and the circulatory systems and blood carrying oxygen.

25	Interviewer	I wanted to ask you if you know anything about cells.
26	L.	Like, cells like if I scraped my skin and put it on a microscope. I know that the cells is just like what makes up everything on your body, like, um…
27	I.	Are there cells in just part of your body? Or are they everywhere?
28	L.	No. It's everywhere. It's even cells on the table, I think. Like, they have…cells make up everything.
29	I.	Like the metal of this chair leg could be made of cells?
30	L.	Probably.
31	I.	So the food goes…so it sort of gets dissolved there and then it passes through here?
32	L.	Yah, and the intestines, they like, I don't know how to explain it…I think the stomach it dissolves the food but not as good as it can be, and then the food…that's the food that goes to waste I guess, and then like vitamins and minerals and stuff I guess are passed to the blood streams from here and all over the body. And from the heart, you know the heart keeps pumping new blood and also what happens…cause your blood needs oxygen and it passes oxygen through your blood streams and in your legs and everywhere, your toes. … I don't think it just comes like right out the stomach and goes to the veins, I'm sure there's something else, but I don't really know about it…
33	I.	Does breathing have anything to do with all this, or is that just something totally different?

34	L.	I think it's different. You have to breathe, but I don't think it has to do with anything eating.
35	I.	And why do you have to breathe, do you think?
36	L.	So oxygen can get into your blood streams, and, cause you have to have…um, I don't know, because, well, I saw it on an educational show, but you have oxygen. It passes through your blood stream.

However, although L. had more "pieces" to work with than T., neither student had a useable understanding of the integrated function of these various organ systems in re. providing working cells with the necessary "raw ingredients" for energy transformation (foodstuffs and oxygen). These brief responses to the clinical pre-interview seem to seem to be consistent with both students' low pre-test scores on both Question Clusters 1 and 2 as indicative of their not having the ability to use either body of content in context.

It was our belief that both these students' scores for both Question Clusters 1 and 2 rising to the same high level (above the class average) in the post-test was indicative of both students' enhanced ability following instruction in *I, Bio* to use both the standards-based and project-based content. We expected to see evidence of this equally for both students. This appeared to be true for T. Compared to her pre-interview, T. was able to reason at length through the post-interview questions with a energy reservoir model of the human body and apply an enhanced understanding of biological energy to describe how to measure the energy in food. T.'s comments begin in response to the same open question used to begin the clinical pre-interview about helping a student stay "healthy."

37	T.	They should like eat, because um, ok, eat the right kinds of food, well that doesn't say what the right kinds of food, eat food, certain amounts of food. And, then work it off by exercising. The food gives you energy so you will have energy to do stuff, but if you don't do eat you will kind of get weak and you won't be healthy.
38	Interviewer	And you said something about energy and exercising works off energy? Is that right? So the food gives you energy too?
39	T.	The food is like your energy because, I can explain it can I draw something?
40	I.	Sure. (hands her a piece of paper)
41	T.	It is like this thing, like this or whatever, what goes in here is energy, from the food, so food energy and then what comes out is work energy. So, like, if you, when the food goes in, certain food stays in and it is used for work energy. And certain food is just dropped, whatever your body doesn't use or whatever your body doesn't really need, it likes comes out.
42	I.	That makes a lot of sense. I want to come back to that, but I want to finish off one other line of questioning, too. I don't know if you remember these pictures from last time, these are just pictures of particular foods and activities. I want to pin you down a little bit more about some choices you might make about things to eat or activities to do. Suppose you again wanted this kid to stay healthy are there some of these you would pick, that would be good for this student to pick?
43	T.	…If you compare, take this and say she had a cheeseburger and then she did weight lifting, so she ate a cheeseburger, how many calories did her body gain? 370. When she does this weightlifting for an hour than her body works off 174 calories, then she still had about like 126 left, then she could do another activity, like something that doesn't take up as much. Like sleeping, she will go to sleep afterwards, that takes up 60 calories, so

		she will still have some energy left. Because calories are food energy, we measure them by calories.
44	I.	But, is there some way we could measure how much energy is in some food, like how much is in this or in that brownie?
45	T.	By the calories probably.
46	I.	And how, so suppose you didn't have this sheet and you wanted to know how much, how many calories was in there, if you were a scientist is there some way you could figure it out?
47	T.	We measured, we took the chip and we made sure it was one gram and we burned it and we put it under this can and it had water in it, and we measured the heat in the water. And we measured before, what the temperature of the water was before and what it was after, and then, like, someway we discovered how much energy was in it, I guess the heat, the heat measured how much energy it was.
48	I.	… Does it sort of make sense in some way that the heat could tell you how much energy?
49	T.	… I forgot what she said, but it is like, it is like 1 gram of tortilla chip and we were trying to figure out how much energy it was. And, I guess how much energy it had, how much heat it had was how much energy it had.

However, although L. had the same high post-test score in Question Cluster 2 as T., L. was not equally adept in the clinical post-interview at reasoning with this content about energy and the body as a biological energy reservoir when compared to T. L. cannot do much more than talk about the vitamins and minerals in food giving you energy, and she cannot apply ideas about energy to measure the energy in food.

50	Interviewer	You get to say what choices that student makes for the next few days to stay healthy. What kind of choices do you think?
51	L.	To eat food from all groups and to exercise, and most of us get exercise in gym, so…
52	I.	Eat food from all food groups, so what does that mean exactly?
53	L.	Like fruit, vegetables, meat, poultry, dairy.
54	I.	And why is it important to eat all those things? … But vegetables have something else you need?
55	L.	Vegetables have iron in it and iron is for energy, or helps…you keep your energy up.
56	I.	Iron helps keep your energy up. Would you say it gives you energy, or does it just make you feel energized?
57	L.	I think it gives you energy, or in a way it could make you feel…
58	I.	So here's my question: suppose it didn't say it on the bag and we were scientists and we wanted to figure out how many calories were in that bag of chips. Do you know how we would figure out, figure it out?
59	L.	You probably could weigh it or um see like um the ingredients they put in it. To see what like if the only the chips maybe if only the chips didn't have the amount of calories in it you could take all the ingredients and see the potatoes has such and such calories, the cheese, the salt. And then put them together.
60	I.	But then someone would have to give you the numbers for the calories for each of those parts. What if someone just gave you a block of cheese then and said how much energy's in that cheese. Is there some way some experiment we could do or something to figure it out?

61	L.	If there is, I don't know about it.

These two students with the same high post-test scores for Question Cluster 2 would have contributed to the class's statistically significant gain on Question Cluster 2, however when assessed with the clinical interview, these two students have alarmingly different abilities to apply this project-based content, to associate caloric balance with health and reason about the body as a reservoir of biological energy, and to apply core content about energy to measure the energy in food.

In the second part of the clinical post-interview, the students' performance is reversed. Now it is T. who appears to have little ability to reason with the standards-based content about how organ systems work in concert to deliver oxygen to working cells to transform the energy "hidden" in foodstuffs, or how this core content might be applied to measure the energy used up doing work, all in stark contrast to her high post-test scores for Question Cluster 1. She has some vocabulary about the parts of the body, but her ideas about how these parts work together and what for and where the body uses oxygen have remained from the clinical pre-interview unintegrated into a larger framework. As a result, she is unable to use this content to devise a means by which to measure the energy the body uses up.

62	Interviewer	You said that food goes in and then what happens?
63	T.	Ok, then it goes through the esophagus, the trachea, or, the esophagus or whatever. And then it has to flow through some other little things, I don't know, it passes your lung and then somewhere down here, it's like your stomach, your stomach or something like that. And then there's capillaries or whatever, and like oxygen also comes in with the food. And like, when it gets down here this could be the food and then it could break apart, and it flows like, this stores energy somewhere in here, and then when you eat something else maybe more gets stored in there.
64	I.	Energy gets stored right there?
65	T.	I don't know if right here, but after it gets breaked apart here maybe some gets stored here, and little red blood cells carry it to whatever you are working.
66	I.	What was that, what were you saying about oxygen again?
67	T.	Oh, um, I was saying that when the food comes in, the oxygen, this oxygen that goes through your body also, and it also helps your body because, it gets carried through your blood.
68	I.	The oxygen does? Is that what you are saying, the oxygen does?
69	T.	Yeah, the oxygen gets carried through your blood, somewhere in your bronchs, whatever you call, like your lungs. And somewhere in here by your heart, somewhere in here, if your blood doesn't get oxygen it like, I don't know how to explain it, but it is just like, if we don't receive oxygen, our heart like, it is just like someone suffocating us, if you don't get any oxygen, and then all of a sudden your heart will stop beating. And then you will die because your heart needs oxygen to pump, to keep beating. And it is beating the blood and goes in through the heart and then out through the heart, and then once it has oxygen it continues to beat, or something like that.
70	I.	Let me ask some of these questions in a little bit of a different way. When you go jogging, your heart beats faster, right? So, why is that?
71	T.	Because, you are losing oxygen at the same time that you are getting it. Yesterday we did this project thingy, mini project thing. And, one way we

		Yesterday we did this project thingy, mini project thing. And, one way we can collect to see how much oxygen a person loses or gains while they are working or bicycling, or something like that. A person is like running, and then they stop, they are running a mile, which will probably take an average person 7 or 6 minutes. And every two minutes they can stop off and blow in a balloon and put the balloon thingy over an oxygen sensor. And that will tell you how much oxygen that this person lost in that one breath, or whatever. So, your heart is moving oxygen, when you are running, and it is starting to beat faster.
72	I.	So, when you run your heart loses oxygen that's why, is there some reason you need more oxygen when you are running? Why is that? Why do you need more oxygen?
73	T.	Because you need oxygen when you are running, because, to keep your heart going. It is like, your heart needs oxygen more than anything else in your body, so if you are losing oxygen from here, your heart is going to stop beating.
74	I.	… Is there some reason that your body needs more energy if you are running, too? Is that part of the story of why your heart beats faster?
75	T.	Your body needs energy to run because, if you don't have enough energy you can't really do anything. (Yawns.) Like right now I need energy, and my body is not functioning as well as if I had more energy. So if this person is running and it's losing oxygen but when it comes out it is carbon dioxide but some oxygen also comes out. And then it's losing oxygen, this heart is losing oxygen and it needs more oxygen. So, if you are breathing in, like you are feeling (pants) you start to breathe harder because you need more oxygen, and you need energy to do everything your body is doing. So, energy and oxygen are like friends. Like because, they need each other. The heart, your body needs both so like, it's not like you can have one without the other, like if you have food comes in and oxygen comes in, your body needs both to function. Because the oxygen goes to the heart and the energy goes to all your working muscles.

However, L. with the same post-test scores for Question Cluster 1 appears quite adept at applying the same standards-based content in response to the post-interview questions.

76	Interviewer	Would it make sense to say your body stores energy? Does your body store energy?
77	L.	… If something happened and you couldn't eat, I think um your body uses up the stored energy. Or the stored energy goes to um like cells working. … The working cells use the stored energy. … We had to figure out from the mouth, and how did it get down to the working muscle cell, the food and the oxygen.
78	I.	And how did that, how did that work?
79	L.	Well, the food it went down, it came from the mouth and down the esophagus… …stomach…it went down the small, I think either the large intestine or was it the small, I can't remember if it was the small or large, but then it went to the villus and um the waste of the food, that like the part you didn't need, it would break off at the villus. And the waste would go through the small intestines out of your body. I can't really remember what happens. It would go to the capillary and then something. … It would eventually pick up the oxygen and it would go back through the

		um, it would pick up the blood cell with the oxygen in the right side of the heart and somehow get it back down…
80	I.	… Why does it need to pick up oxygen?
81	L.	Because the cell needs oxygen to keep going.
82	I.	You might know that when you jog, your heart beats faster, right? Can we…why is that? Can we explain that in terms of this picture at all?
83	L.	I think it beats faster because you're jogging and the um cells are working a lot more harder and moving a lot more faster. So the blood…the heart is pumping faster to get the blood and the energy and the oxygen faster to the working cells.
84	I.	Are there any other body systems that need to be working with the heart when that happens?
85	L.	The lungs. Because you're gonna have to, you need more oxygen so you're breathing harder um so the um oxygen can travel all over your body for the cells also.
86	I.	Is there some way you could measure the amount of energy, the amount of work your body is using when you jog or exercise like this?
87	L.	Well, we used an oxygen sensor. And um we measured how much oxygen we used up and before we did any exercise, um I had…before I did any exercise there was 21% oxygen in the air I brothe out. And then when I finished running there was only 16%. So that, um, if you're…You could tell I was working a lot because I used up more of the oxygen…
88	I.	How does that tell you about the energy you used exactly?
89	L.	… Because when you're running you breathe harder and, like I said before, it's so you can get the oxygen to the working cells. And you um breathe back out and then there's less oxygen in there, then you're using up more oxygen.

Again, these two students with the same high post-test scores for Question Cluster 1 that contributed to the class's statistically significant gain for Question Cluster 1 have very different abilities to apply this standards-based content. L. has an organized knowledge of organ systems that can explain how these systems work in concert to provide working cells with the "raw materials" to transform energy in the human body. She can make accurate predictions for how the system will respond to increased work and can apply the results of these predictions to "inventing" a means by which to measure the energy used up doing work. This is a meaningful understanding of this content that supports L.'s high score for question cluster one on the post-test. However, T., with an identically high post-test score, is shown by the clinical post-interview to have a dramatically inferior understanding of how to use this knowledge in context.

Conclusions and Discussion:

We suggested that a project-based science unit like *I, Bio* if properly designed would teach standards-based life science content in the context of its curricular project as well as additional project-based content required to complete the project. It was also anticipated that being introduced to either body of core content with a need for using this content in the project context would better prepare learners to apply this content in novel problem-solving situations as well as support improvement on standards-based assessments in re. both bodies of content. The *I, Bio* pre- and post-test was carefully designed as a "proximal" measure of achievement based on the particular content addressed in the unit but lying at some remove from the actual activities of the unit. For this reason, we believed that improvement on the test was also indicative of students being better able to apply aspects of this content to new contexts. Assuming this, we can interpret the results of the unit pilot as being quite successful, with participating students' scores improving by statistically significant amounts for both the standards-based as well as the project-based content. However, in reviewing clinical pre- and post-interview data for students whose pattern of scoring from the pre- to the post-test was comparable to the class-wide changes measured with this instrument, we found that the test is a much blunter instrument than we expected for assessing the ability to use either body of content. Although it bears more investigation, it does not appear reasonable to assume that pre- to post-test movement is indicative of an improved ability to apply content learned to new contexts, although it may reasonably indicate an improvement on standards-based assessments. This was a surprising finding because even with the pre- and post-test instrument being limited in the kinds and number of tasks that could be assigned in the time available, the designers felt the instrument would serve as a useful indicator of content mastery. Although such a test in comparison to the clinical interview remains much more efficient to administer and quantify, the clinical interview results appear to far more accurately assess students' ability to use science content in a project-based context, and to some extent contradict the test results. Although both students T. and L. improved significantly from pre- to post-test in both Question Clusters 1 and 2, moving from below to above the class average, student T. appeared to have a useful understanding of only the project-based content but not the standards-based content, and vice versa for student L. Neither student had a useful understanding of <u>both</u> bodies of content, although both bodies of content were learned in the context of completing the curricular project. If these results prove to be at all indicative of even a subset of students in the pilot study, they point to the need for a combination of test data with clinical interview data to assess content knowledge, and with this lens the *I, Bio* unit pilot shows mixed success.

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Table 1

***I, Bio* Test Results by Question Cluster**

	No. Items	Pre	Post	Diff.	[illegible]	ES[a]
Total	21	7.87	9.76	1.89^{***}	3.71	0.51
Question Cluster 1 (cells and organ systems content; items 02, 04, 06a, 06b, 08, 09a, 09b, 10a, 10b, 10c, 14)	11	3.78	4.37	0.59^{*}	1.89	0.31
Question Cluster 2 (energy reservoir content; 01, 03, 05, 07, 11, 12, 13, 15a, 15b)	9	3.54	4.72	1.17^{***}	1.91	0.62

[a]Effect size: Effect size was calculated by the difference between the means divided by the standard deviation around the pre-test scores.
$^{*}p<.05$; $^{**}p<.01$; $^{***}p<.001$.

Table 2

Item-Level I, Bio *Pre- and Post-Test Results*

Item	Type[a]	Pre	Post
01	MC	0.37	0.54
02	MC	0.89	0.85
03	MC	0.46	0.76^{**}
04	SCR	0.50	0.46
05	MC	0.67	0.65
06a	MC	0.83	0.85
06b	SCR	0.30	0.35
07	MC	0.28	0.67^{***}
08	MC	0.70	0.65
09a	SCR	0.13	0.24
09b	SCR	0.04	0.13
10a	MC	0.09	0.06
10b	MC	0.13	0.24
10c	MC	0.06	0.09
11	MC	0.33	0.46

12	SCR	0.48	0.61
13	SCR	0.74	0.80
14	MC	0.11	0.46***
15a	MC	0.15	0.11
15b	SCR	0.06	0.11
16	MC	0.54	0.67

[a] Type: MC = multiple choice, SCR = short constructed response.
*p<.05; **p<.01; ***p<.001.

Table 3

***I, Bio* Test Results by Question Cluster**

		Total		Question Cluster 1		Question Cluster 2	
Subject	Level[a]	Pre	Post	Pre	Post	Pre	Post
D.	High	15	17	7	7	7	9
G.	High	19	21	9	11	9	9
H.	High	9	11	4	4	4	6
J.	Medium	4	8	2	4	2	4
L.	Low	5	11	3	5	2	5
T.	Low	6	11	2	5	3	5

[a]Level: Achievement level assessed by teacher based on grades, participation, and standardized test scores.

APPENDIX 1: Pre/Post Test Items

Use the following paragraph to answer question 1.

Jane woke up at 8:00 a.m. this morning. After spending the morning sitting around and thinking, Jane ran four miles in the early afternoon. She used up 400 units of energy while running. Jane spent the rest of the afternoon until 6:00 p.m. cleaning up around the house, using up an additional 150 units of energy.

1. How many units of energy did Jane use up from 8:00 a.m. to 6:00 p.m.?

    A. Less than 550 units of energy
    B. Exactly 550 units of energy
    C. More than 550 units of energy
    D. More than 750 units of energy

2. Which is the most basic unit of living things?

    A. Cells
    B. Bones
    C. Tissues
    D. Organs

3. Which of the following statements BEST explains why you do not need to eat all of the time?

    A. You do not need energy to do some activities.
    B. You can feel energetic, even when you do not have much energy.
    C. Your body also gets energy from rest and exercise.
    D. Your body is able to save some energy to use later on.

4. Your heart and stomach are both made up of cells. The heart pumps blood while the stomach makes acid. Do you think the cells in your heart will be the same as or different from those found in your stomach? Explain your answer.

Use the following paragraph to answer question 5.

Diego woke up at 6:30 a.m. and ate breakfast. His breakfast had 350 units of energy in it. Diego exercised for a few hours, using up 300 units of energy. After eating a lunch with 250 units of energy in it, Diego went swimming with friends until 3:00 p.m. He used up 450 units of energy while swimming.

5. According to the paragraph, did Diego gain or lose energy over the period from 6:30 a.m. to 3:00 p.m.?

A. He gained more than 100 units of energy
B. He neither gained nor lost units of energy
C. He lost less than 100 units of energy
D. He lost more than 100 units of energy

6. Immediately before and after running a 50 meter race, your pulse and breathing rates are taken. What changes would you expect to find?

   A. no change in pulse but a decrease in breathing rate
   B. an increase in pulse but no change in breathing rate
   C. an increase in pulse and breathing rate
   D. a decrease in pulse and breathing rate
   E. no change in either

   Explain your answer.

7. Which of the following foods gives you the MOST energy per ounce?

   A. Apple
   B. Brownie
   C. Cucumber
   D. Water

8. Which of these is NOT a function of the blood?

   A. Digesting food
   B. Protecting against disease
   C. Carrying waste materials away from the cells
   D. Carrying oxygen to different parts of the body

<u>Use the following paragraph to answer question 9</u>.

Mindy has been training to run in a marathon. She often takes her dog Rusty with her when she goes running. Finally, race day arrives and Mindy registers for the race.

9. After the race, Mindy eats a large meal. Mindy's body needs and uses the nutrients from the meal.

   a. Name **two** body systems involved in getting nutrients from the food that Mindy eats.

   b. Describe the primary function of each system.

10. Below is a sentence with three blanks (A, B and C) for you to fill in. Below the sentence is a list of possible terms for each blank. Choose the correct term for each

blank from the list. The list has only one correct term for each blank. WRITE THE NUMBER of the correct term next to the appropriate letter on your answer sheet.

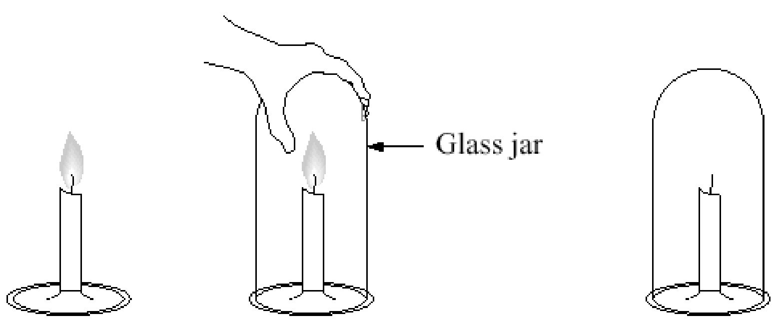
After food is digested in the stomach, ___(A.)___ carrying energy enter small blood vessels in the ___(B.)___ from which they are carried to ___(C.)___.
1. atoms
2. brain
3. cells
4. flows
5. heart
6. intestines
7. molecules
8. organ

11. All of the following are true statements about energy EXCEPT?

    A. Energy comes in many forms, including light and sound energy.
    B. Energy can be destroyed when it changes from one form to another.
    C. Energy can change from one form to another in living things.
    D. Energy cannot be created. It can only be changed from one form to another.

12. Two boys, John and Lamar, are the same age and height. John weighs 130 pounds while Lamar weighs 90 pounds. Both boys play soccer every day after school. Which boy uses more energy while playing soccer? Explain your answer.

13. When a glass jar is placed over a lighted candle, the flame goes out.



Why does this happen?

14. The energy your body gets from the food you eat is changed into the work your body does

    A. by the digestive system.
    B. by the heart.
    C. inside the body's cells.
    D. inside muscles and bones.

15. Owen uses up an average 650 units of energy per day. On average, how many units of energy should Owen take in per day to ensure good health over the long term?

    A. Slightly less than 650 units of energy
    B. Exactly 650 units of energy
    C. Slightly more than 650 units of energy
    D. Significantly more than 650 units of energy

    Explain your answer.

16. What is the BEST reason for including fruits and leafy vegetables in a healthy diet?

    A. They are rich in minerals and vitamins.
    B. They carry enough calcium to meet the body's needs.
    C. They are the best source of protein.
    D. They provide more energy than most other foods.

APPENDIX 2: Clinical Interview Protocol

I, Bio Clinical Interview: Part 1

<u>Materials</u>:

- **Simplified food & activity nutritional labels**
- Colored pencils
- Body drawing
- Blank paper

<u>INTRODUCTION</u>

My name is XXXXXXX. I'm a student/researcher at Northwestern working with your teacher and with your school to develop new and better science curricula.

Today I want to ask you some science questions. Some of these questions are related to what you've been doing in your science class, but some of them aren't really about things that you've learned yet. So you're probably not going to be very sure about many of the answers. That's okay. We're really just interestred in how you think about these things; we're not really interested in whether you get answers right or wrong. This doesn't count for anything. It's not a test. So, I'm hoping you'll tell me as much as you can about what you think about the questions that I'm going to ask. Just talk, and I'll listen and ask questions.

Any questions before we start?

<u>The modes we're trying to activate in this section</u>:

- health/strength/good for you
- weight loss/diet
- balance the energy
- fitness mode- strength/strong/flexible
- anti getting sick mode

<u>A. Undirected choices to stay healthy</u>

Imagine a student like you, they're in the same grade (boy or girl, depending on interviewee)... and you need to make sure that they stay healthy for the next 2 or 3 days. You get to say what choices that student makes for those days to keep them healthy.

What kinds of things should they do?

1. <u>If no mention of food</u>:
    a. What about food?
    b. What things does he/she need to eat to stay healthy? Why?
2. <u>If no mention of activities</u>:
    a. What about activities?
    b. What things does he/she need to do to stay healthy? Why?

B. Directed Choices to stay healthy

Here are a bunch of things to choose from (give students nutritional labels). You can choose the ones you want for the imaginary student, as much of each one as you want.

Why did you pick these?

> *<interviewer repeats choices if necessary>*

- What did you look at to decide what choices would keep the student healthy?
- What do these things do for the student that keeps her/him healthy?

<general probe; based on student response take one of the three following tacts, and then return to activiate other two "modes">

C. Vitamins & Minerals

1. Why didn't you pick spinach? Why might it be a good idea to pick spinach?

> *Follow Up:* Some kids said that it was the vitamins and minerals that they had to worry about <u>most</u> to keep the student healthy. What do you think about that?

2. Do these things (vitamins/minerals) do anything for the student's body to keep it healthy?
    - What?
    - What happens if they don't have enough?

3. Now that you've thought about it a little bit, do you want to change your choices?
    - Why?
    - Why not?
    - Why did you decide to change to XXX?

4. Are any of your choices giving her/his body vitamins/minerals? How do you know?

D. Vitamin Stores

- Do you need to eat vitamins/minerals every day? Why?
- If the student eats a lot of vitamins/minerals one day, can they eat less the next day?
- Does something use them that you'd need to eat more vitamins/minerals some days vs. other days?
    - Does it depend on what you're doing/eating?
    - What does it depend on?

How do you know all this? How did you find it out?

E. Weight loss/diet Mode

1. Why didn't you pick ultra slim-fast?

> *Follow Up:* Some kids said that it was the student's weight that they had to worry about most to keep the student healthy. What do you think about that?
>
> - Does weight have anything to do with keeping the student's body healthy? What?
> - What happens if the student doesn't weigh enough?

2. Do you want to change your choices now?
   - Why?
   - Why not?
   - Why did you decide to change to XXX?

Are any of your choices to change her/his weight?

What about your choices has to do with changing her/his weight?
How do you know?

> *Follow Up:* When you chose these foods did you think about calories? Did you think about that when you were choosing activities?

F. Weight Balance

1. Do you need to keep your weight the same every day? Why?

2. If you eat a lot one week, can you eat less the next week?

3. Are there some things that change your weight that makes it lower some times vs. other times?
   - What does it depend on?
   - Does it depend on what you're doing/eating?

4. Does the student need to replenish their body's weight all the time, every second?
   - Does something decrease the weight that student's body needs more to stay healthy?
   - What would you need to increase?

How do you know all this? How did you find it out?

G. Energy Balance Mode

1. What if someone's going to be doing a whole lot? Does that change your choices?

2. Why did/didn't you pick brownies?
Are there any reasons why brownies might be a good choice?

> *Follow Up:* Some kids said that it was the student's energy that they had to worry about <u>most</u> to keep the student healthy.
> - What do you think about that?

3. Does energy have anything to do with keeping the student's body healthy? What?

4. Do you want to change your choices now?
   - Why?
   - Why not?
   - Why did you decide to change to XXX?
   - Are any of your choices changing her/his body's energy?

5. What about your choices has to do with changing her/his body's energy? How do you know?

> *Follow Up:* When you chose these foods did you think about calories? Did you think about that when you were choosing activities?

H. Energy Stores

1. Do you need energy every day, all the time? Why?

2. If you get a lot of energy one week, can you get by with less the next week?

3. Does something use up energy that the student's body needs more to stay healthy? (Thinking? Heart beating? Lift your arm like this?)

4. What would increase the student's body's energy?

5. Does food have energy inside of it? Where is the energy in food?

How do you know all this? How did you find it out?

I. Fitness mode: strength/strong/flexible

What's good about jogging? weight lifting? stretching?
- Does that help the student stay healthy?

J. Anti getting sick mode

Imagine that the rest of your family has the flu, what would you do if you want to stay healthy?

- Would you do anything different than what you normally do?

I, Bio Clinical Interview: Part 2

Materials:

- Simplified food & activity nutritional labels
- **Colored pencils**
- **Body drawing**
- **Blank paper**

The modes we're trying to activate in this section:

- Just because that's what your body does
- Movement of stuff
- Part of stuff taken in is used up for; parts going here and there for various reasons

We expect these to be less stably pre-existing modes and more emergent in the circumstances

A. Health and Food systems questions

Now I want to ask you some questions about what your body does with the things we just talked about that keep you healthy.

1. We just discussed what things your body needs most to be healthy.
   - What happens to them once you eat them?
   - Do these things need to go somewhere in your body? Where?

These are the things in the foods you chose to have the student eat, right? (list choices)

2. How do the things you said were healthy before get out of the food, and get to the places in your body that need them?

B. Drawing Where Food Goes

Here's a picture of a body and some colored pencils, can you draw where the food goes and label all the parts that you know while you're explaining it to me?

Name the parts and/or the systems involved in where the food goes. Name and label as many parts and systems as you can. Don't worry if you don't know some of it, just tell me what you do know.

- *What each does have to do with getting what the body needs most for health to where?*

- What do these parts/systems do? What role do they play?

  Follow up: Ask about other typical parts/systems, esp. if the student doesn't name them explicitly- circulatory, respiratory, skeletal, muscular, nervous, lungs, stomach, brain, heart, intestines, bones, muscles).

What do these systems have to do with how your body gets what it needs from food?
- How do they work?
- Do they work together? How?

C. Energy Specific Questions about Food

1. What about the idea that your body needs to keep up its energy to be healthy?
   - Does your body need the same things to keep up its energy as keep it healthy?
   - What parts and/or systems involved with this? Can you draw that for me?

2. Where is the energy in all of what you just drew?
You said earlier there was energy in food; where does the energy go?

3. What does the energy need to get to in your body?
   - How does it get out of your food and get there?
   - Where along the way does the energy come out? How?

Draw and label along the way. Name the parts and/or the systems involved and say what each does in re. getting energy in food to where? What do these parts/systems do?

D. Role of air/oxygen/respiratory system:

1. *Does breathing have anything to do with getting the energy out of food?*
   - What?
   - What how does breathing help you get the energy out?

2. Where does the energy in food end up?
- Is it used up there?
- By what?

3. Have you heard of cells?
- Can you explain to me what they are?
- Do they use up the energy in food? How? To do what?
- Which cells use up energy? All cells?

<parts/systems involved in cellular respiration including CELLS; also foreshadowing systems integration question>

E. Systems Integration Questions

1. When you exercise, your heart beats more, right? Why do you think this happens?
2. Are any other body parts/systems we talked about working with the heart when this happens?
3. What about when you exercise and you breathe more too?
4. Does this have anything to do with your heart beating more? What?

How do you know all this? How did you find it out?